D1.8 – Specification and design for the 5kW stack

CLEAN HYDROGEN JU Grant Agreement no. 826204			
Project acronym:	**DOLPHIN**		
Project title:	**D**isruptive pemfc stack with n**O**vel materia**L**s, **P**rocesses, arc**H**itecture and optimized **IN**terfaces		
Funding scheme:	Collaborative Project, Small or medium-scale focused research project		
Topic:	FCH-01-6-2018: *Game changer fuel cell stack for automotive applications*		
Start date of project:	01/01/2019	Duration	60 months
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Document properties			
WP 1 : Stack architecture development and mod.		WP leader: SYMBIO	
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		Approval by WP leader	
		Approval by coordinator	

Dissemination level	**Public** (i.e. only for consortium and FCH-JU)	
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Revisions			
Version	Date of changes	Author	Changes
1.0	29/02/2024	J. Rapior	
2.0	13/05/2024	J. Rapior, J. Pauchet	Final version

TABLE OF CONTENTS

GLOSSARY

Symbol or acronym	Unit	
AL	-	Active Layer
GDL	-	Gas Diffusion Layer
L	m	Thickness of the AL

PUBLISHABLE SUMMARY

WP1 aims at designing a new stack architecture to increase power density (W/cm²), reduce mass (kg), reduce interface resistances, and reduce volume (m^3) of the stack, keeping in mind that the cost projection of the final object is a key driver for its industrialisation. It specifies the 5 kW stack tested in WP5, based on a 100 kW for full-power application beyond DOLPHIN. This includes analysing new designs and materials within the Fluidics and Electrical Core, the Electrochemical Core, the Interface Diffusion Medium, and the Integrated Terminal Plate, as well as manufacturing processes.
WP1 gives inputs to WP2, WP3, WP4, and WP5. Iterative loops between WPs 1, 2, 3, 4 and 5 are necessary to optimize the materials and designs according to the targets of DOLPHIN and to the manufacturing capabilities. Specifications of the components (material, design) will thus be updated along the project considering the properties and performance as measured in WP2, WP3, WP4, and WP5. This will be done from single cell up to the full-power stack.

This WP is also in charge of the 5 intermediate milestones to select the components/EC/EFC for performance and durability tests along the project, and of the last milestone which defines the final size of the stack.

This deliverable is based on the D1.3, and is a specification of the 5kW stack (Test Platform 4) that will be tested in WP5.

LIST OF FIGURES

1. PROJECT TARGETS AND HYPOTHESIS

1.1. Overall project targets

INDICATORS	Int. SoA 2017 (AutoStack Core)	DOLPHIN (~ FCH-JU 2024 targets)
Weight-specific power density (kW/kg) at nominal power	3.4	≥ 4.0 (≥ +18%)
Volumetric power density (kW/l) at nominal power	4.1	≥ 5.0 (≥ +25%)
Area-specific power density (W/cm²) at 0.66 V	1.13	2.0 (+75%)
Cost (€/kW) at 100 000 units/year	36.8	< 20 (-45%)
Durability (hours)	3,500	6,000 (+70%)
Stack max operating temperature (°C)	95	105 (+10°C)

1.2. 100kW stack specification summary

The TP4 is a short stack version of the DOLPHIN's 100kW stack (for project timing and cost reasons). It is usually admitted that a short stack (>10 cells) is enough to assess the performances and stability (flooding/drying) of a technology. Only some scale effects will not be seen, like end cells performances, end cells flooding, fluidic distribution between every cells, compression effects and compression behavior.

The 100kW stack was dimensioned using the go/no go criteria of the project (1.45 W/cm² at 0,66V) and a maximum voltage of 400V (so 400 cells) to be compatible with passenger car electrical architecture without using an expensive buck/boost DCDC convertor.
100000 W / 400 cells = 250 W/cell @1.45 W/cm² ➔ **175cm² of active area per cell**

General	Max stack voltage (OCV)	400	V	Passenger car architecture (400V boost-only DCDC)
	Max cell number	400	cells	1V/cell @OCV
	Active area	175	cm²	To reach 100kW at max power with 400 cells
	Total area	384	cm²	45% active_area / total_area ratio

The power density target is 5 kW/L and 4 kW/kg. This indicator will give us the maximum size of the stack (100kW / 5kW/L = 20 L total volume): cells dimensions, cell pitch, end plates size. The cells dimensions have been defined in D1.6.

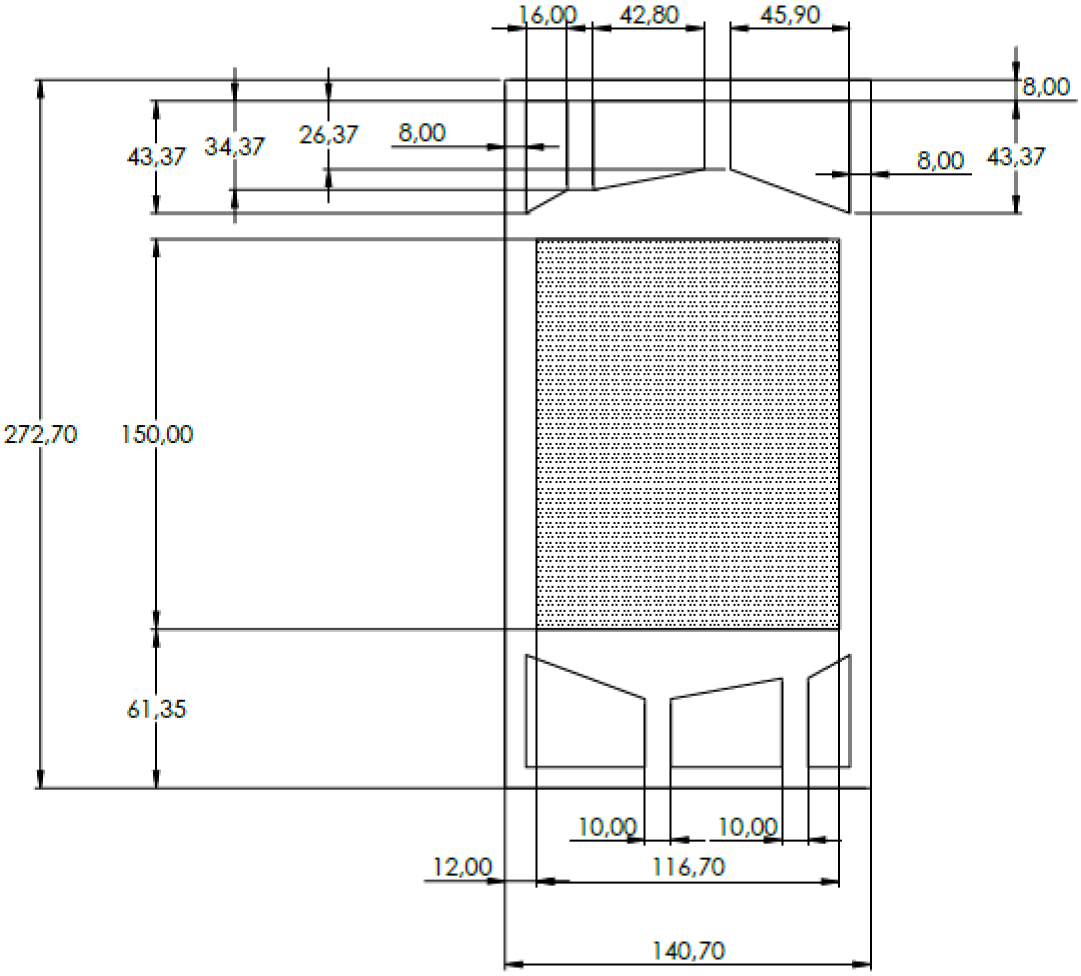

Figure 1 - TP4 EFC dimensions

For size constraints, the selected technology for the 100kW stack is not the tie-rods system, but must be something more compact.

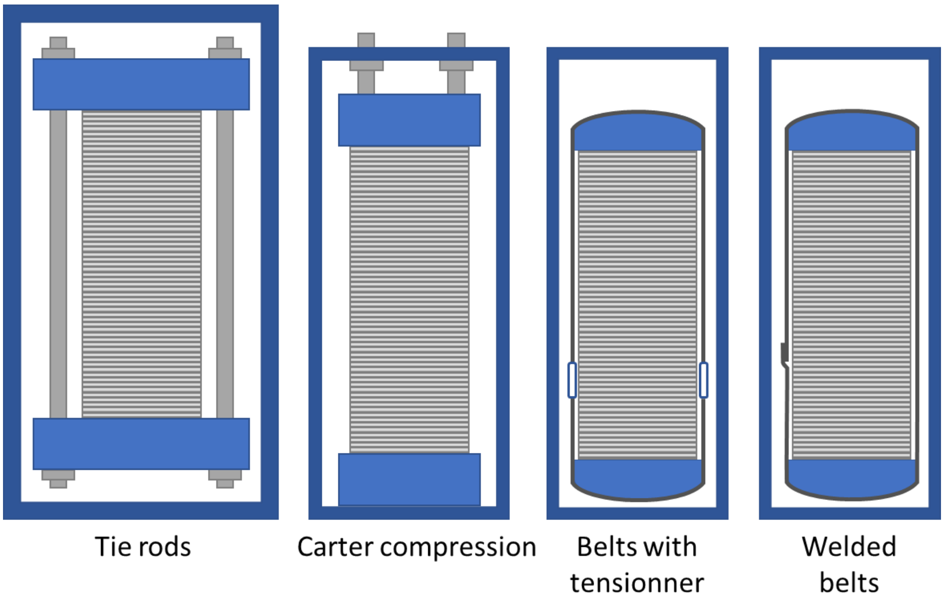

Figure 2 - Stack compression technologies

After defining the end plates according to the cells dimensions, we can define the detailed dimensions allowed for the cells and the end plates. We see that if we must fit 400 cells in 418mm, the cell pitch must remain below 1.04mm (taking in account the monopolar plates at the two ends).

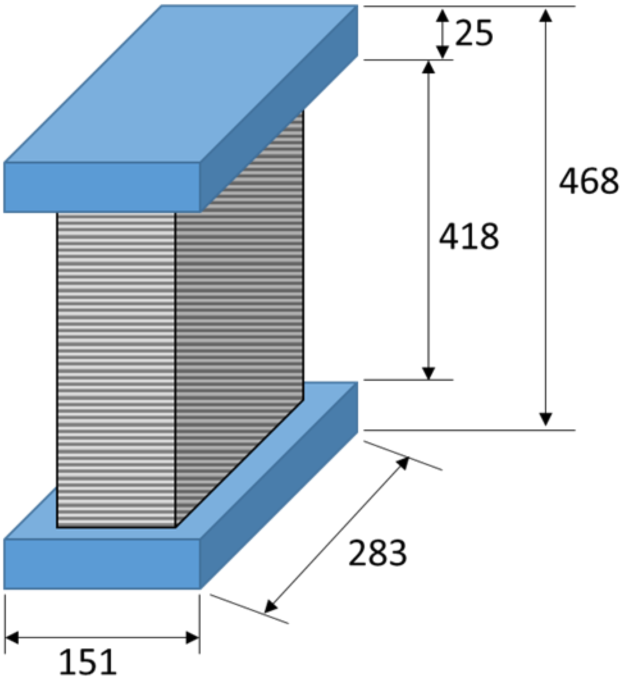

Figure 3 - 100kW maximum dimensions

2. 5kW STACK SPECIFICATION

2.1. Overall dimensions and end plates

The **TP4 stack is a short stack version of the 100kW stack**. So **it will use the same cells**. Each cell having a power of min 250W, we would need a maximum of 20 cells to reach 5kW.
Concerning the end plates, this time we have no constraints on the power density (who will be low regarding the volumic part of the end plated). We can choose a more prototype-friendly compression technology than for the 100kW stack, and the tie-rods are the easiest choice. We should also use thicker (and so stiffer) terminal plates, because the bending defects will be diluted in a smaller amount of cells.
The overall dimension targets and end plates rigidity are given in the tables below.

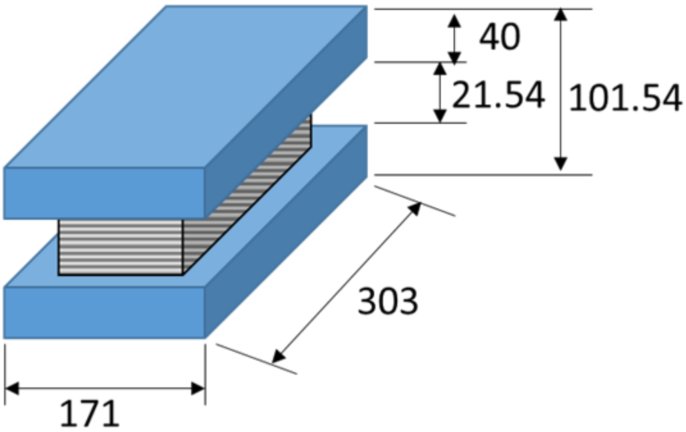

Figure 4 - 5kW stack overall dimensions

Mechanical performances of end plates :

End plates max flatness (machining tol + beding) in active area, perp to flow field	0.05	mm	20% contact resistance difference between center and edges
End plates max flatness (machining tol + beding) in active area, parallel to flow field	0.05	mm	20% contact resistance difference between center and edges
End plates max overall flatness (machining tol + beding)	0.2	mm	gasket compression sensivity, and EFC bending

2.2. Performances

General	Max stack voltage (OCV)	20	V	
	Cell number	20	cells	
	Active area	172	cm²	To reach 100kW at max power with 20 cells
	Total area	383	cm²	45% active_area / total_area ratio

Max power (Under system conditions)	Stack power	5	kW	
	Cell voltage	0,66	V	
	Power density	1,45	W/cm²	Go/no go criteria
	Stack voltage	13,2	V	
	Stack current	379	A	Not over 400A, for safety contactors and DCDC disponibility
	Cooling outlet temperature	90	°C	For vehicle's front radiator easy dimensionning
	Max inlet/outlet temperature difference	12	°C	

Medium power (Under system conditions)	Cell voltage	0,76	V	
	Cooling outlet temperature	85	°C	For vehicle's front radiator easy dimensionning
	Max inlet/outlet temperature difference	10	°C	
Nominal power (Under system conditions)	Cell voltage	0,8	V	Best efficiency, low degradation
	Cooling outlet temperature	82	°C	
	Max inlet/outlet temperature difference	8	°C	
Low power (Under system conditions)	Cell voltage	0,84	V	Max voltage for durability issues
	Cooling outlet temperature	80	°C	
	Max inlet/outlet temperature difference	8	°C	

Overall performances	Max cathode pressure drop	300	mbar	Pressure in/out homogeneity & humidifier dP resistance
	Max anode pressure drop	100	mbar	Recirculation systems efficiency
	Max cooling pressure drop	350	mbar	To keep low absolute pressure in the stack
	Maximum hydrogen losses during purges	2	% of total H2 consumption	
	Maximum N2 concentration at anode	30	%_mol of total gas composition	
	Stack minimum storage temperature	-40	°C	
	Min ambiant temperature in usage	-20	°C	

	Peak stack temperature un usage	105	°C	
	Pt loading max at anode	0,1	mg/cm²	
	Pt loading max at cathode	0,4	mg/cm²	
	Max H2 cell flow deviation from average	5	%	
	Max air cell flow deviation from average	5	%	
	Max cool cell flow deviation from average	10	%	
	Life duration in driving cycle conditions	6000	H	
	Start-stop cycles	20000	cycles	5 per day during 10 years
	End of life criteria : max power reached at	0,6	V	

2.3. Environmental constraints

Environmental constraints			To be Checked during Dolphin project
H2 Quality	SAE2719		
Air Quality - particules	DIN 71460	For particules, dust filtration	
Air Quality - pollutants	CO <0,2(µMol/Mol) HCHO <0,2 (µMol/Mol) HCOOH <0,2(µMol/Mol) CO+HCHO+HCOOH <0,2(µMol/Mol) H2S Base <0,004(µMol/Mol) NH3 <0,1(µMol/Mol) Halogen Comp total <0,05 (µMol/Mol)		
Cooling Fluid	DI Water		x
Storage Temperature	-40°C to 85°C		
Start Time (25°C)	15sec	0 to 90% Power	
Cold start time (0°C)	30sec	0 to 90% Power	
Freeze start time (-20°C)	60sec	0 to 50% Power	
Vibration	IEC 60068-2	pass	
Gravel Bombardment	ISO 16750-4	pass	

IP protection	ISO 20653	IP67 - IP6K9K	
Fluids	ISO 16750-5	pass	
Salt Spray	ISO 16750-4	pass	
Electrical Disturbances	ISO 11452	pass	

3. ACKNOWLEDGEMENT

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No **826204**. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation program, Hydrogen Europe and Hydrogen Europe Research.